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(54) Title: DATA TRANSMISSION METHOD, DATA TRANSMISSION SYSTEM, AND CELLULAR RADIO SYSTEM

(57) Abstract

The present invention relates to a data transmission method, data transmission system and a cellular radio system employing information channels having at least two different capacities, the speech transmitted on said channels being coded in such a manner that on a channel having a higher capacity, essentially fewer symbols to be transmitted are coded from the same speech signal block than on a channel having a lower capacity. In order to extend the coverage area of the cellular radio system of the invention, the coverage area of the base station (BTS) comprises an inner coverage zone (50), on which frequency hopping is not applied, and an outer coverage zone (51), which employs an information channel having a lower capacity, the signal transmitted on said channel being speech coded according to a channel of a higher capacity, and that channel coding is performed on the speech coded data in such a manner that the number of symbols corresponds to the channel of a lower capacity, and frequency hopping being applied on said channel.

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Data transmission method, data transmission system, and
cellular radio system

The present invention relates to a data
transmission method in a system employing information
channels having at least two different capacities, on
which channels speech is transmitted by at least two
different coding techniques in such a manner that on a
channel having a higher capacity, essentially fewer
symbols to be transmitted are coded from the same speech
signal block than on a channel having a lower capacity.

In designing data transmission systems,
especially cellular radio systems, two essential aspects
have to be especially taken into account. Firstly, the
required geographical area is to be covered at low costs.
Secondly, information is to be transmitted with the
smallest possible transmission errors.

It is typical of digital data transmission
systems in which speech information is transmitted that
they apply speech coding, the purpose of which is to
change analog speech into a digital form. For instance in
a fixed telephone network, analog speech is changed into a
digital signal the bit rate of which is 64 kbit/s. In many
data transmission systems, for instance in cellular radio
systems, this transmission rate is impractical since it
requires too much transmission capacity. The speech coding
used in these systems is thus implemented, if possible, by
using a transmission channel and a bit rate as small as
possible.

Speech coding techniques are constantly studied,
and thus, for instance in designing cellular radio
systems, the development of technology has been taken into
account by making an allocation in the system for the use
of better speech coding algorithms. This is the case for
instance in the GSM system, in which is specified a so-

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called half rate codec, the bit rate of which is half of
the bit rate of a so-called full rate codec. With the use
of a half rate codec, the capacity of the system can thus
be increased, since the amount of bits to be transmitted
5   is half of what is used to be. For instance in TDMA
systems, it is thus possible to transmit a double amount
of coded speech in the same time.

In constructing a radio telephone system,
attempts are thus made to produce a desired coverage area
10   at lowest possible cost. In considering the location of
the base stations of the system, both the required traffic
capacity and the produced cell size are taken into
account. In areas where the expected amount of traffic is
great, cell sizes are small, whereas in sparsely populated
15   areas where the required traffic capacity is small,
attempts are made to produce as large cells as possible.
Transmission capacities used at base stations and terminal
equipments thus increase. In some cases where it is
uneconomic to construct a dedicated base station, it is
20   possible to use a separate repeater, which receives
signals arriving from a base station and repeats them
within its own area. Costs can thus be reduced to some
extent, but not significantly, however.

Accordingly, an object of the present invention
25   is to extend the cell size of a radio telephone system and
thus the coverage area of the system without great changes
in the equipment and particularly without an increase in
transmission power. A further object of the invention is
to implement advantageously a cellular system cell which
30   has an essentially larger coverage area than before,
without the used transmission capacities increasing
essentially, however.

This is achieved with the method described in the
introduction, characterized in that a signal transmitted
35   on at least one channel having a lower capacity is speech

coded according to a channel of a higher capacity, and
that channel coding is performed on the data speech coded
in this manner in such a manner that the obtained number
of symbols corresponds to the channel of a lower capacity.

The invention further relates to a data
transmission system employing information channels having
at least two different capacities, the speech transmitted
on said channels being coded by at least two different
coding techniques in such a manner that on a channel
having a higher capacity, essentially fewer symbols to be
transmitted are coded from the same speech signal block
than on a channel having a lower capacity. The data
transmission system of the invention is characterized in
that a signal transmitted on at least one of the system's
information channels having a lower capacity is speech
coded according to a channel of a higher capacity, and
that channel coding is performed on the data speech coded
in this manner in such a manner that the obtained number
of symbols corresponds to the channel of a lower capacity.

The invention further relates to a cellular radio
system employing information channels having at least two
different capacities, the speech transmitted on said
channels being coded by at least two different coding
techniques in such a manner that on a channel having a
higher capacity, essentially fewer symbols to be
transmitted are coded from the same speech signal block
than on a channel having a lower capacity, said system
having at least one carrier frequency at which frequency
hopping is used. The cellular radio system of the
invention is characterized in that in at least some cells
of the system, the coverage area of the base station
comprises an inner coverage zone, which employs an
information channel of either a lower or higher capacity
on which frequency hopping is not applied, and an outer
coverage zone, which employs an information channel having

a lower capacity, the signal transmitted on said channel being speech coded according to a channel of a higher capacity, and that channel coding is performed on the data speech coded in this manner in such a manner that the obtained number of symbols corresponds to the channel of a lower capacity, and frequency hopping being applied on said channel.

The method of the invention thus utilizes half rate speech coders developed for different systems, which speech coders thus use half of the channel resources of full coding. In the method of the invention, speech is coded with half rate coding algorithms but is channel coded to be transmitted on a full coding rate channel. The channel coding can thus be implemented so well that the system operates at a signal level lower by almost 6 dB than in a situation where speech is transmitted on a half coding rate channel. This enables an increase of about 50% in the radius of the coverage area of a cell. The solution of the invention thus enables sparsely populated areas to be covered with fewer base stations than before.

The method of the invention can naturally also be applied in connection with speech coders operating at low rate other than half rate coders. In the following, the invention will be described, however, by using half rate coding as an example, without restricting the invention to it, however.

The method of the invention can be applied particularly advantageously in connection with frequency hopping. The method of the invention can be applied in a cellular radio system to increase the coverage area by establishing two coverage areas in a cell, the inner one of which corresponds to a coverage area implemented by conventional means and the outer one to a coverage area enabled by the method of the invention, in which area frequency hopping and half rate coding on a full rate

channel are used.

In the following, the invention will be described in more detail with reference to the examples according to the accompanying drawings, in which

5   Figure 1 illustrates schematically a part of a cellular radio system in which the method of the invention can be applied,

Figure 2 illustrates a known method for performing channel coding in the case of a full rate

10   codec,

Figures 3a - 3e show the method of the invention for performing channel coding and interleaving in the case of a half rate codec,

Figure 4 illustrates signal-to-noise ratios in

15   different coding solutions,

Figure 5a illustrates schematically the coverage area of a cell of a cellular radio system, and

Figure 5b illustrates schematically the coverage areas of a cell of the cellular radio system according to

20   the preferred embodiment of the invention.

The method of the invention can be applied in any digital data transmission system in which several different speech coding rates can be used and in which different transmission channels are provided for these

25   coding rates. One such data transmission system is the GSM cellular radio system, which will be used as an example in the following while describing the preferred embodiment of the invention, without restricting the invention to it, however.

30   Figure 1 illustrates schematically a part of the GSM cellular radio system. In the cellular radio system, the area covered by the system is divided into radio cells. Two base station controllers BSC1 and BSC2 are connected with digital transmission links 12 to a mobile

35   exchange MSC. Further, base stations BTS1, BTS2 and BTS3

and BTS4 are connected with digital transmission links 1 to the base station controllers BSC1 and BSC2, respectively. Each BSC and the base stations connected to it constitute a base station system BSS. Typically, the radio coverage area of one base station BTS constitutes one radio cell. Each base station BTS1 - BTS4 has a predetermined, fixed number of physical radio channels. The GSM system is described in more detail for instance in M. Mouly, M-P. Pautet: The GSM System for Mobile Communications, 1992, ISBN 2-9507190-0-7, which is incorporated herein by reference.

A physical channel of the GSM system consists of TDMA frames, each of which contains a certain number of time slots, by which logic channels are transferred. In using a conventional, so-called full rate codec, each physical channel has preferably eight time slots. The logic channels include traffic channels for calls established with subscriber terminal equipments MS located in a cell.

In the following, it is first described how channel coding is implemented in the present GSM system in the case of a full rate codec. In the GSM system, a full rate codec produces data blocks the length of which is 260 bits. Data blocks are generated at intervals of 20 ms. Channel coding is performed on such a data block, which results in a coded data block, which contains 456 bits, which are interleaved into eight time slots. Errors occurring over the transmission link are present in the received speech signal in different ways depending on where the defective bit is located in the data block. All bits of the data block are not equivalent, but some bits are more significant than others due to coding techniques. Because of this, conventional channel coding is performed by dividing a data block into three parts according to the importance of the information contents of the bits

contained by these parts, and each part is treated in a different manner.

Figure 2 illustrates the composition of a data block produced by a full rate codec and the division thereof into different parts. The data block comprises three parts, Ia, Ib and II, which comprise 50, 132 and 78 bits, respectively. The bits of part Ia are coded by adding three error detection bits to the bits, whereafter the part is convolution coded with efficiency ratio 1/2. The efficiency ratio of convolution coding refers to the ratio of actual data bits and all bits to be transmitted. The convolution coding increases the number of bits to be transmitted due to redundant bits produced as a result of the coding. The bits of part Ib are convolution coded directly with efficiency ratio 1/2. Part II is not coded in any manner. The length of the coded data block obtained in this manner is thus 456 bits, which are thus interleaved into different time slots by dividing the data block to be transmitted in eight time slots, in order to minimize the effect of errors taking place over the transmission link.

The following is a description of a known manner of performing channel coding in the present GSM system in the case of a half rate codec. In the GSM system, a half rate codec produces data blocks the length of which is 112 bits. A data block is divided into two parts, the first part being convolution coded with efficiency ratio 1/2 and the second one not being coded. This results in a 228-bit data block, which is interleaved into four half rate time slots.

The following is a description of how channel coding is performed in the method of the invention when a half rate codec is used. Figure 3a illustrates the composition of a data block produced by a half rate codec and the division thereof into different parts. As in the

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case of a full rate codec, a data block comprises three
parts, Ia, Ib and II, which in the method of the invention
comprise 73, 22 and 17 bits, respectively. The 22 bits of
part Ib are coded by adding three error correction bits to
5   the bits. The error correction polynome used has the form
$G_{CRC}(D) = D^3+D^2+1$. The obtained data block is in accordance
with Figure 3b at this stage.

For convolution coding, two five-bit groups are
added to the data block to the end of parts Ib and II
10   according to Figure 3c. Thereafter, parts Ia and Ib, which
now thus comprise 73+22+5=103 bits, are CC(4,1,5)
convolution coded together with efficiency ratio 1/4. Part
II, which now comprises 17+5=22 bits, is CC(2,1,5)
convolution coded with efficiency ratio 1/2. Thus is
15   produced a data block which is in accordance with Figure
3d. The number of bits of parts I is thus 412 and that of
part II is 44. The total number of bits of the data block
is thus 456, which corresponds to the length of a data
block used on a full rate channel.

20   In the method of the invention, the signal coded
with a half rate codec is transmitted on a full rate
channel as interleaved into eight time slots. The
interleaving is illustrated in Figure 3e. The figure shows
two successive data blocks D and E. Each 456-bit data
25   block is divided into eight parts D0 - D7 and E0 - E7,
respectively, each of which comprises 57 bits. In the
interleaving, bits from two different data blocks are
disposed in each time slot according to Figure 3e. 114
data bits are thus transmitted in each time slot.
30   Interleaving is described in more detail for instance in
the reference Mouly, Pautet mentioned above.

Since the number of the original data bits was
112, and there are 456 bits to be transmitted and not 228
as in the known method, channel coding can be implemented
35   much more efficiently than before. As a result of the

method, a signal can be received with a worse signal-to-noise ratio without sacrificing the quality of the signal, since the errors over the transmission link can be detected and prevented better than before due to more efficient channel coding.

Figure 4 illustrates achieved signal-to-noise ratios in different coding and channel solutions. The horizontal axis indicates the signal-to-noise ratio of a received signal in decibel units. The figure shows four different signal-to-noise ratio values in different coding and channel alternatives in such a manner that the value concerned refers to the signal-to-noise ratio which is required in the corresponding alternative in order that the quality of the received signal would be satisfactory. The quality of the received signal can be evaluated for instance with the FER criterion. The lower the signal-to-noise ratio by which the system achieves sufficient signal quality, the larger the coverage area achieved will be.

Point A1, which thus corresponds to signal-to-noise ratio 12.0 dB, is achieved by using a solution according to prior art by transmitting a signal coded with a half rate codec on a half rate channel without frequency hopping. A corresponding solution, implemented with the method of the invention, of transmitting a signal coded with a half rate codec on a full rate channel without frequency hopping produces a signal-to-noise ratio according to point A2, i.e. 9.4 dB. The gain achieved with the solution of the invention is thus 2.6 dB.

Point A3, which thus corresponds to signal-to-noise ratio 6.5 dB, is achieved by using a solution according to prior art by transmitting a signal coded with a half rate codec on a half rate channel while using frequency hopping. A corresponding solution, implemented with the method of the invention, of transmitting a signal coded with a half rate codec on a full rate channel while

using frequency hopping produces a signal-to-noise ratio according to point A4, i.e. 1.6 dB. The gain achieved with the solution of the invention is thus 4.9 dB.

In both of the examples given above, one thus employing frequency hopping and the other being implemented without frequency hopping, a distinct improvement in the required signal-to-noise ratio is achieved with the method of the invention. This results in the fact that in a cellular radio system applying the method of the invention, a significantly larger coverage area is achieved when the same transmission power is used.

Figure 5a illustrates schematically the conventional coverage area 50 of a cell of a cellular radio system. The cell typically comprises one base station BTS, which communicates with the subscriber terminal equipments MS1 - MS2 located within its area. Figure 5b illustrates schematically the coverage areas of a cell of the cellular radio system according to the preferred embodiment of the invention. In the preferred embodiment of the invention, the coverage area of a cell consists of two coverage areas, the inner one 50 corresponding to the coverage area of a conventional cell and the outer one 51 corresponding to an extended coverage area achieved with the method of the invention.

As stated earlier, the solution of the invention is particularly useful when frequency hopping is utilized in the system. In the GSM system, implementing frequency hopping means in practice that a base station is provided with two or more transceiver units, one of which does not use frequency hopping but the other units may apply frequency hopping. This is due to the fact that in the GSM system, each base station must transmit a so-called broadcast control channel BCCH at a fixed frequency. The following is an exemplifying description of the preferred application of the method of the invention in a cellular

radio system cell, which employs two transceiver units, one transmitting at a fixed frequency and the other utilizing frequency hopping.

5   The coverage area of the cell is divided into two areas according to Figure 5b. The terminal equipments MS1 and MS2 located near the base station communicate with the base station by using a fixed frequency. Either a conventional full rate codec or a half rate codec on a half rate channel can be used at the frequency. Terminal
10   equipments MS3 - MS4, which are located outside the conventional coverage area 50, communicate with the base station by using the solution of the invention by transmitting a signal coded with a half rate speech codec on a full rate channel while utilizing frequency hopping.
15   An increase of about 50% in the coverage area is thus achieved in the cell as compared with a conventional arrangement. When a terminal equipment moves from a coverage area into another, it must thus perform an intra-cell handover.

20   Even if the invention has been described above with reference to the examples according to the accompanying drawings, it will be apparent that the invention is not so restricted but it can be modified in various ways within the scope of the inventive concept set
25   forth in the appended claims.

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Claims

1.   A data transmission method in a system employing information channels having at least two different capacities, on which channels speech is transmitted by at least two different coding techniques in such a manner that on a channel having a higher capacity, essentially fewer symbols to be transmitted are coded from the same speech signal block than on a channel having a lower capacity, c h a r a c t e r i z e d in that a signal transmitted on at least one channel having a lower capacity is speech coded according to a channel of a higher capacity, and that channel coding is performed on the data speech coded in this manner in such a manner that the obtained number of symbols corresponds to the channel of a lower capacity.

2.   A method according to claim 1, c h a r a c - t e r i z e d in that the speech coded data block comprises 112 symbols and that the speech signal block is divided into three parts (Ia, Ib, II), which comprise 73, 22 and 17 symbols, respectively, and that 3 error correction symbols are added to the middle 22-symbol part (Ib), and that the first two parts (Ia and Ib) are combined and 5 known tail symbols are added thereto, and that the 103 symbols obtained in this manner are convolution coded with efficiency ratio 1/4, and that 5 known tail symbols are added to the posterior 17-symbol part (II), and that the 22 symbols obtained in this manner are convolution coded with efficiency ratio 1/2.

3.   A method according to claim 2, c h a r a c - t e r i z e d in that the convolution coded symbols are transmitted as interleaved during eight time slots.

4.   A data transmission system employing information channels having at least two different capacities, the speech transmitted on said channels being

coded by at least two different coding techniques in such
a manner that on a channel having a higher capacity,
essentially fewer symbols to be transmitted are coded from
the same speech signal block than on a channel having a
5   lower capacity, c h a r a c t e r i z e d   in that a
signal transmitted on at least one of the system's
information channels having a lower capacity is speech
coded according to a channel of a higher capacity, and
that channel coding is performed on the data speech coded
10   in this manner in such a manner that the obtained number
of symbols corresponds to the channel of a lower capacity.

5.   A cellular radio system employing information
channels having at least two different capacities, the
speech transmitted on said channels being coded by at
15   least two different coding techniques in such a manner
that on a channel having a higher capacity, essentially
fewer symbols to be transmitted are coded from the same
speech signal block than on a channel having a lower
capacity, said system having at least one carrier
20   frequency at which frequency hopping is used, c h a r -
a c t e r i z e d   in that in at least some cells of the
system, the coverage area of the base station (BTS)
comprises an inner coverage zone (50), which employs an
information channel of either a lower or higher capacity
25   on which frequency hopping is not applied, and an outer
coverage zone (51), which employs an information channel
having a lower capacity, the signal transmitted on said
channel being speech coded according to a channel of a
higher capacity, and that channel coding is performed on
30   the data speech coded in this manner in such a manner that
the obtained number of symbols corresponds to the channel
of a lower capacity, and frequency hopping being applied
on said channel.

6.   A cellular radio system according to claim
35   5, c h a r a c t e r i z e d   in that subscriber terminal

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equipments (MS1, MS2) located near the base station (BTS)
communicate with the base station on the non-frequency
hopping information channel, and that terminal equipments
(MS3, MS4) located further from the base station (BTS)
5   communicate with the base station on the frequency hopping
information channel.

7.   A cellular radio system according to claim 5,
c h a r a c t e r i z e d in that a subscriber terminal
equipment moving from a coverage zone into another
10   performs a base station (BTS) internal handover.
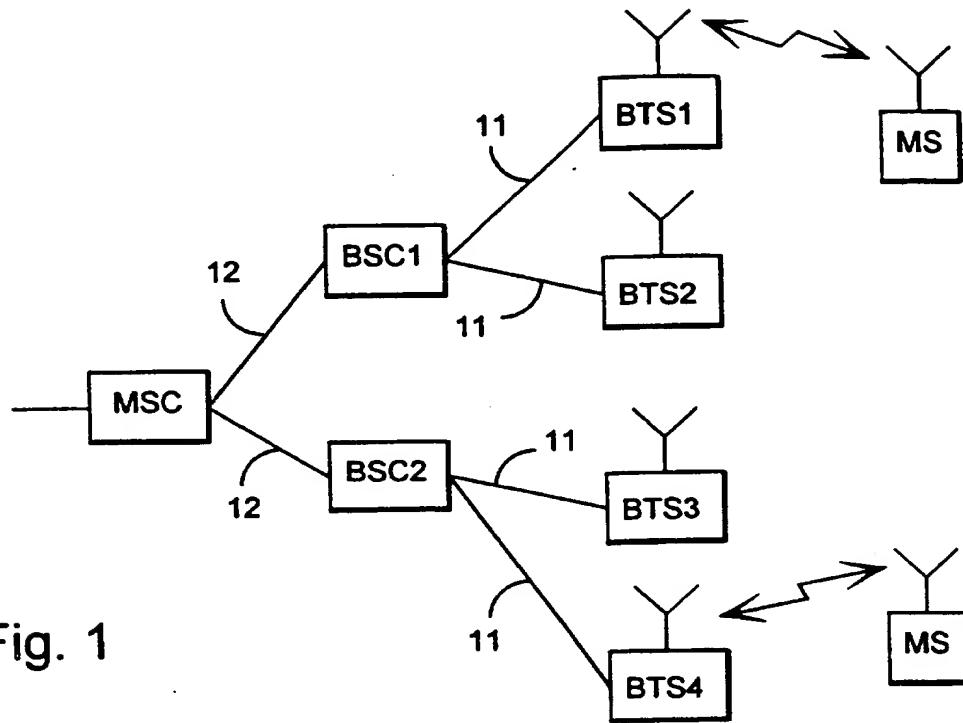
Fig. 1
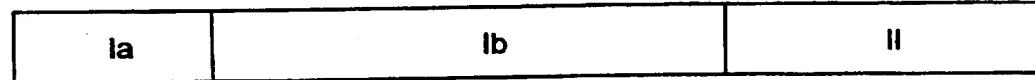
Fig. 2

Fig. 3a

Fig. 3b
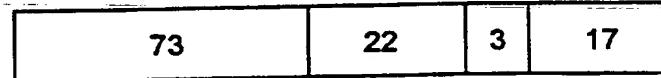
Fig. 3c

Fig. 3d
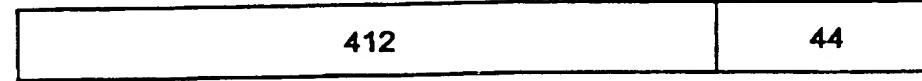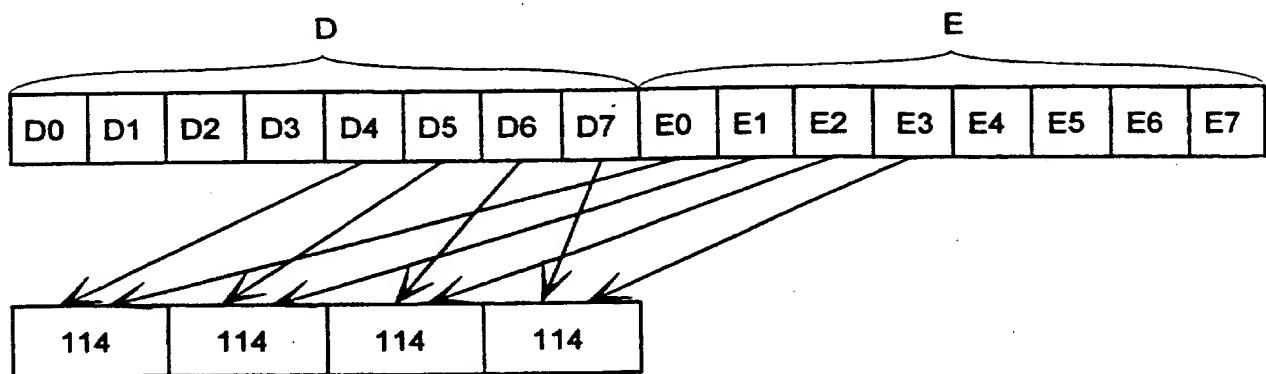
Fig. 3e
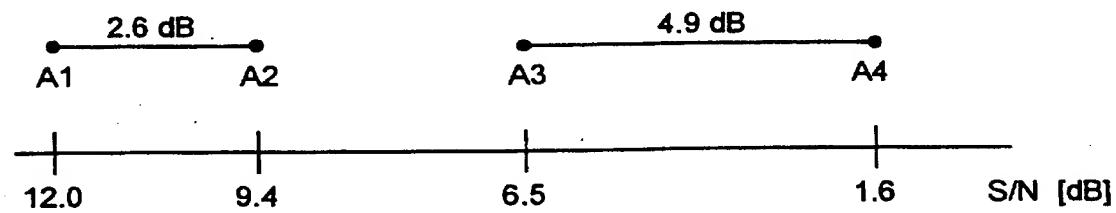
Fig. 4
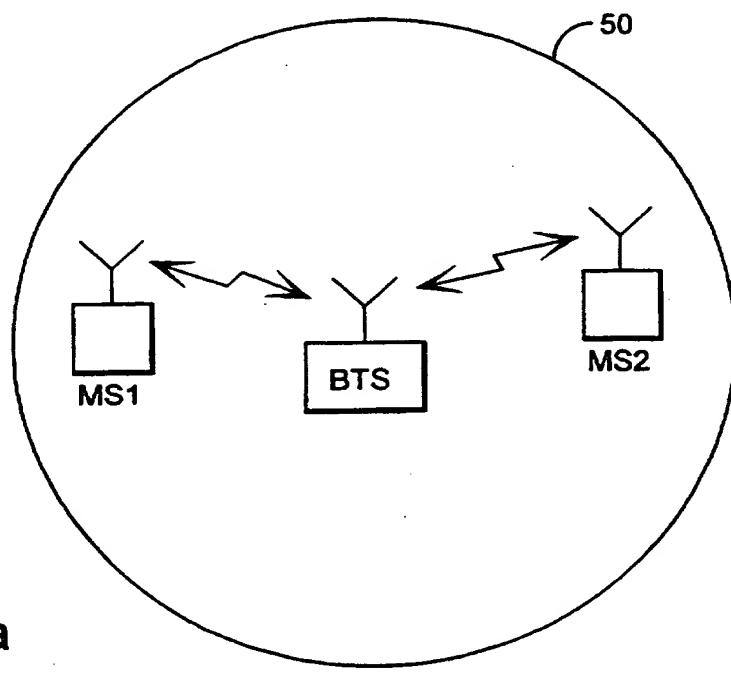
Fig. 5a
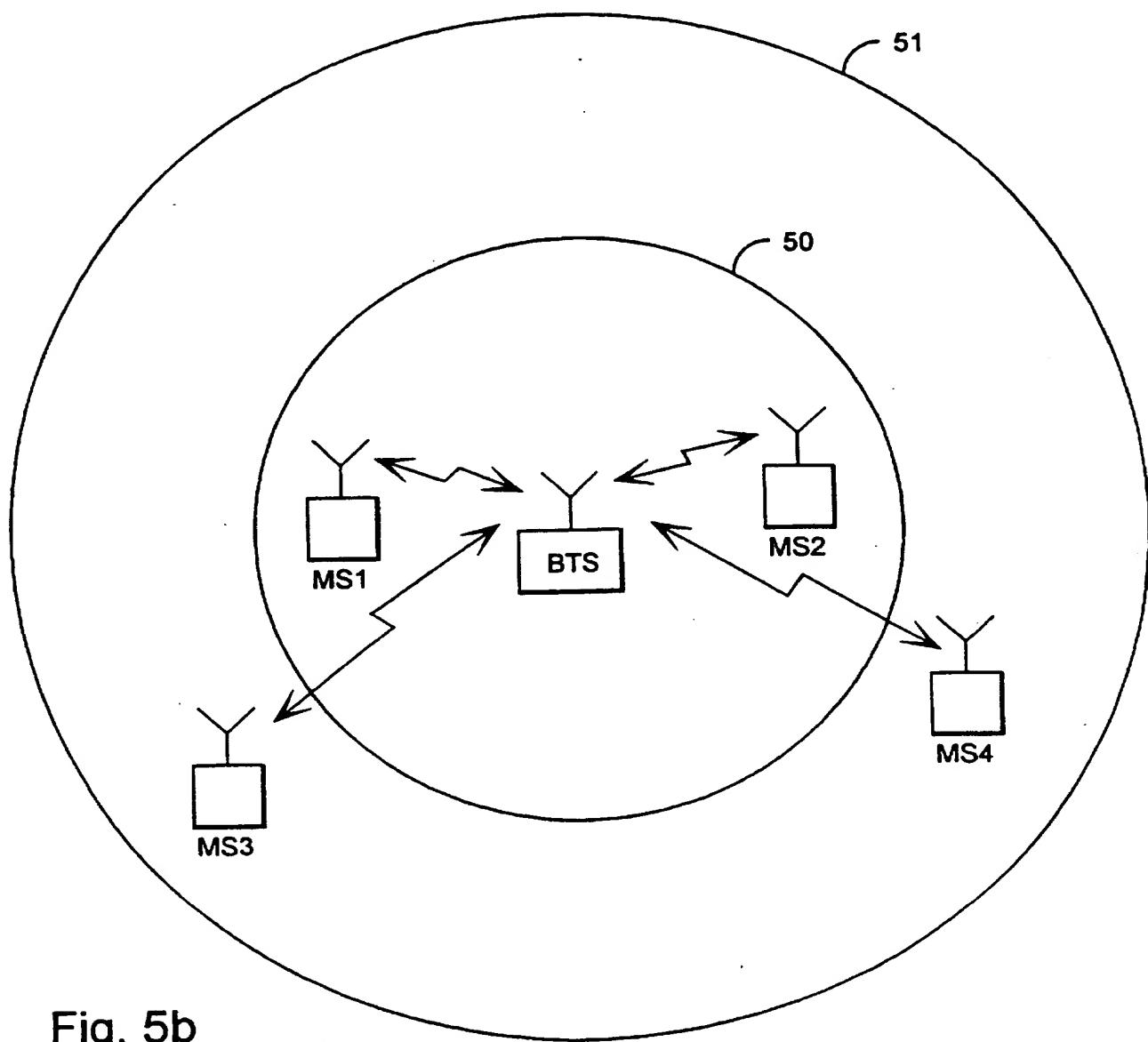
Fig. 5b

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04B 7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04B, G10L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0472511 A2 (TELEFONAKTIEBOLAGET LM ERICSSON), 26 February 1992 (26.02.92), claim 1	1-9
A	IEEE International Conference on Acoustics, Speech and ....., Volume 1, 1994, (New York), Jörg-Martin Müller et al, "A CODEC CANDIDATE FOR THE GSM HALF RATE SPEECH CHANNEL", page 257 - page 260, see especially ch 2.2	1-9
A	EP 0584865 A1 (PHILIPS ELECTRONICS UK LIMITED), 2 March 1994 (02.03.94), abstract	1-9

[X] Further documents are listed in the continuation of Box C.   [X] See patent family annex.

* Special categories of cited documents:

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 April 1996	0 3 -05- 1996

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C (Continuation).   DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9407313 A1 (ANT NACHRICHTENTECHNIK GMBH), 31 March 1994 (31.03.94), abstract	1-9

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Patent document cited in search report		Publication date	Patent family member(s)		Publication date
EP-A2-	0472511	26/02/92	AU-B-	642760	28/10/93
			AU-A-	8261991	27/02/92
			CA-A-	2049712	24/02/92
			JP-A-	4234232	21/08/92
			NZ-A-	239283	27/09/94
			US-A-	5327576	05/07/94
EP-A1-	0584865	02/03/94	NONE		
WO-A1-	9407313	31/03/94	NONE		

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